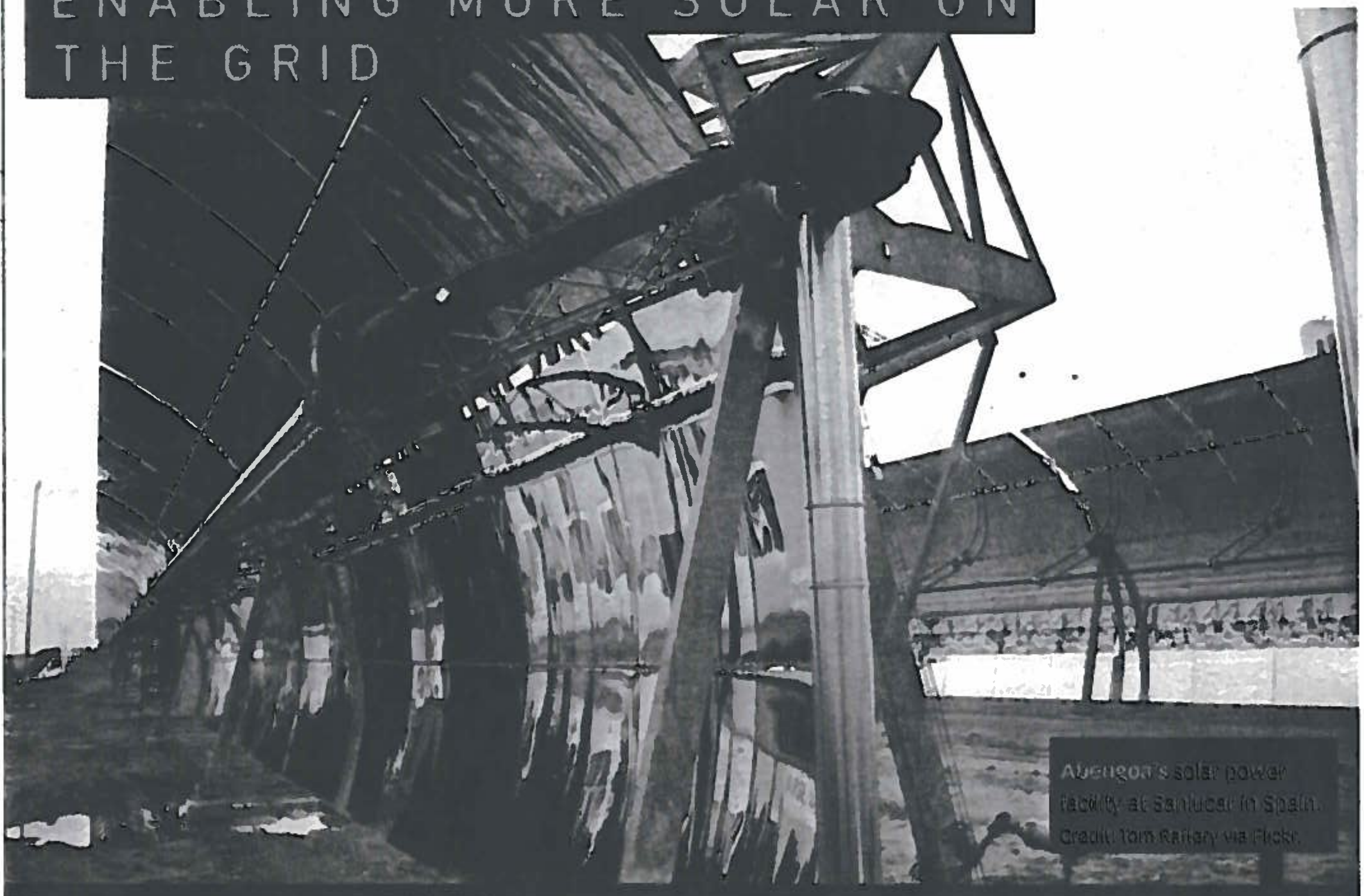
CSP With Thermal Storage: ENABLING MORE SOLAR ON THE GRID



Abengoa's solar power facility at Sanlucar in Spain. Credit: Tom Raftery via Flickr.

The cost of PV has been plummeting, and it has a cost advantage over concentrating solar power (CSP). But CSP has the advantage of storage, which means that teamed with PV, it can improve the benefits and bottom lines of both technologies.

Bill Scanlon, National Renewable Energy Lab

Peak demand for electricity in the United States typically hits between 4 p.m. and 8 p.m., which doesn't quite line up with the sun's schedule. It's fortunate that the sun is high in the sky during many of the hours when the air conditioning is in demand. But in summer, people tend to need air conditioning during the dinner hour and beyond, when kitchen appliances are whirring, lights are on, and TVs are blaring.

To the rescue comes concentrating solar power (CSP), a technology being tested and deployed by utilities in America's deserts and southern Spain.

New analysis at the U.S. Department of Energy's (DOE) National Renewable Energy Laboratory (NREL) has found that CSP, with its greater grid flexibility and ability to store energy for as long as 15 hours, can enhance total solar power generation and actually give photovoltaic (PV) systems a greater presence on the grid.

Thermal Storage Can Even Out the Bumps

Like Edison and Tesla or Dempsey and Tunney, the two major solar energy technologies never meant to play nice. Each had its niche — and its dreams of market share.

But that's changing, said NREL analyst Paul Denholm, co-author with Mark Mehos of the study "Enabling Greater Penetration of Solar Power via Use of CSP with Thermal Energy Storage."

Think of power from PV as a roller coaster of highs and lows, and power from CSP, via thermal energy storage, as a gently rolling train.

PV panels and wind turbines contribute electricity to the grid, but without the ability to store that power, they cannot supply the grid after the sun sets, or after the wind dies. Large fossil-fueled and nuclear power plants can't be quickly stopped or started to accommodate variable energy sources such as solar and wind energy.

CSP can even out these ebbs and flows because it can store power and ramp up output when the amount of direct wind or solar power drops.

"It all gets down to grid flexibility," Denholm said. "What sets of grid technologies do you deploy to make the grid respond faster and over a greater range to the input of variable energy such as solar and wind?

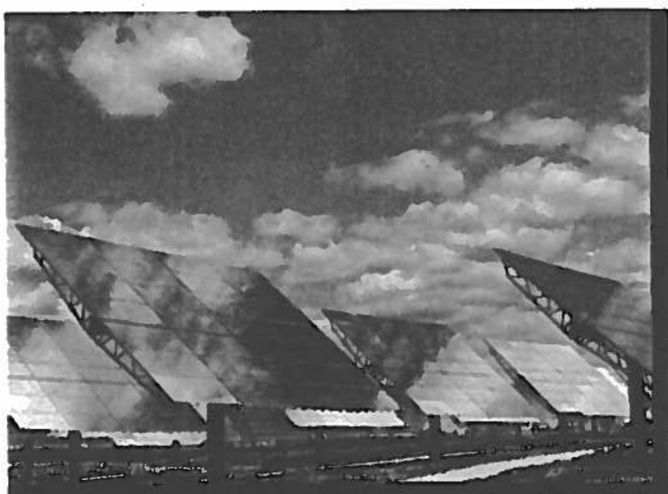
A CSP plant works by heating a heat transfer fluid that is used to boil water to make steam. But because of thermal inertia, by the time that fluid gets through the system's pipes to the power plant, perhaps 10 or 15 minutes have passed.

When a cloud passes over a PV panel, the drop in energy production is immediate. But because of the 10 or 15 minutes of thermal inertia, a cloud passing over a CSP tower doesn't cause this immediate drop. Nor is there the immediate surge when sunlight returns.

"The change is more gradual," Denholm said. "That's one reason CSP can bring a greater quality to the grid."

Still, the greater potential for CSP — and for CSP helping PV to expand its role on the grid — is its capacity to store the energy it captures from the sun for several hours, making it a source of reliable energy after the sun sets.

"CSP can fill in that gap in the evening when there's peak demand for electricity," Denholm said. "Together, the solar resource can provide all that peak demand. And together they can reduce or eliminate the need to build new power plants for those peak periods."



Mirrors from an Abengoa solar plant in Spain. Credit: Langalex via Flickr.

Crews work around the clock installing mirrored parabolic trough collectors — built on site — that will cover 3 square miles at Abengoa's Solana Plant in Ariz. Credit: Dennis Schroeder, NREL

Molten Salts a Low-Cost Solution

Thermal energy storage at CSP plants "is low-cost because it's not exotic," Denholm said. "It's some large tanks with some media to store energy before you use it to boil the water." The best medium for storage available today is molten salt, NREL's Greg Glatzmaier said.

Molten salts are abundant and not very costly. They behave themselves, neither decomposing nor volatizing at the high temperature needed in a CSP plant — about 565 degrees Celsius (°C).

At a typical molten-salt CSP plant, the salts are stored in two tanks, one much hotter than the other.

In the case of a power tower CSP plant, in which the mirrors focus the sun's rays on one receiver atop a tower, the lower-temperature tank is at about 293°C, while the higher-temperature tank is at 565°C, Glatzmaier said.

The salt is pumped from the "cold" tank to the power tower, where it collects the solar energy that's focused on the receiver, raising its average temperature. The salts then descend into the "hot" tank, where they can maintain this very hot temperature for several days, though typically they are used within hours.

The salt in the hot tank is then sent to a heat exchanger that generates the steam needed to turn the turbines at a power plant. As they exit the steam generator, the salts cool, and by the time they return to the cold tank, they measure at about 293°C.

When the sun is shining, the CSP plant can take the salts out of the cold tank, heat them up at the tower's receiver, and then dump them into the hot tank for storage, Glatzmaier said. "If you come to the end of the day and the hot tank is pretty full, you can keep generating electricity by withdrawing the salts from the hot tank to generate steam."

CSP Power Plants with Storage: Project Updates

Abengoa Solar is building a 250-megawatt CSP plant near Gila Bend, Ariz. that will cover 1,900 acres and use 900,000 mirrors to direct sunlight to heat a working fluid inside its tubes. The plant boasts six hours of thermal storage.

The 19.9-MW power tower run by Gemasolar near Granada in southern Spain is configured to store enough energy during the summer to provide solar-generated electricity 24 hours a day, Glatzmaier said. In the winter, when there's less sunshine, electricity comes from more conventional sources a few hours each day.

The tanks that hold the molten salts at Abengoa's Solana Plant can keep the solar-heated fluids very hot for several hours, so they can be transferred to turbines to produce electricity when the sun isn't shining. Credit: Dennis Schroeder, NREL

SolarReserve is building the 110-megawatt Crescent Dunes Solar Energy Project near Tonopah, Nev., which will use molten salt to store the sun's energy as heat for several hours.

BrightSource is building an even larger CSP project in the Mojave Desert near Needles, Calif., that will have storage for just a couple of hours a day — but this will be enough to serve more than 140,000 homes during peak hours.

This article was excerpted from a National Renewable Energy Lab feature story. To read the story in its entirety, go to www.nrel.gov/news.

Boosting CSP Production with Thermal Energy Storage

Combining concentrating solar power (CSP) with thermal energy storage shows promise for increasing grid flexibility by providing firm system capacity with a high ramp rate and acceptable part-load operation. When backed by energy storage capability, CSP can supplement photovoltaics by adding generation from solar resources during periods of low solar insolation.

By Paul Denholm, PhD and Mark Mehos, National Renewable Energy Laboratory

The falling cost of solar photovoltaic (PV)–generated electricity has led to a rapid increase in the deployment of PV and projections that PV could play a significant role in the future U.S. electric sector. The solar resource itself is virtually unlimited; however, the actual contribution of PV electricity is limited by several factors related to the current grid.

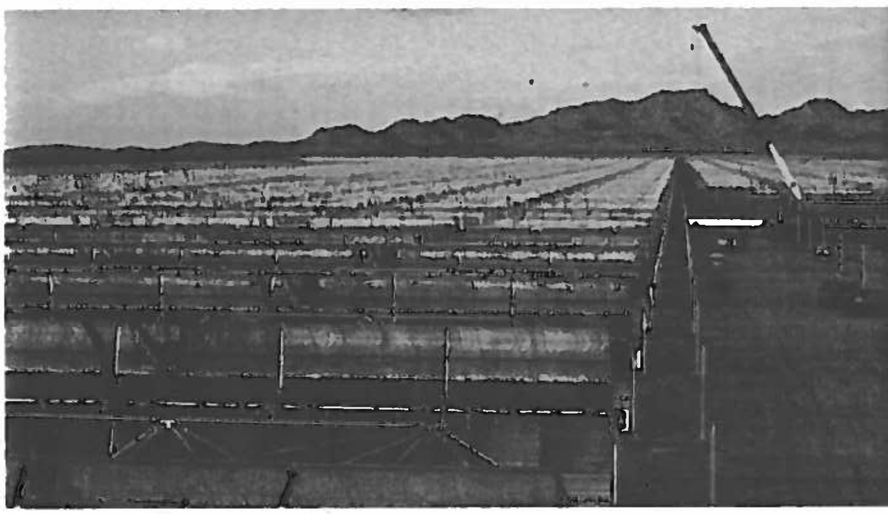
The first is the limited coincidence between the solar resource and normal electricity demand patterns. The second is the limited flexibility of conventional generators to accommodate this highly variable generation resource. At high penetration of solar generation, increased grid flexibility will be needed to fully utilize the variable and uncertain output from PV generation and to shift energy production to periods of high demand or reduced solar output.

Energy storage is one way to increase grid flexibility, and many storage options are available or under development. In this article, however, we consider a technology already beginning to be used at scale—thermal energy storage (TES) deployed with concentrating solar power (CSP).

PV and CSP are both deployable in areas of high direct normal irradiance such as the U.S. Southwest. The role of these two technologies is dependent on their costs and relative value, including how their value to the grid changes as a function of what percentage of total generation they contribute to the grid, and how they may actually work together to increase overall usefulness of the solar resource.

Both PV and CSP use solar energy to generate electricity. A key difference is the ability of CSP to utilize high-efficiency TES, which turns CSP into a partially dispatchable resource. The addition of TES produces additional value by shifting the delivery of solar energy to periods of peak demand, providing firm capacity and ancillary services, and reducing integration challenges. Given the dispatchability of CSP enabled by TES, it is possible that PV and CSP are at least partially complementary (Figures 1 and 2).

1. Concentrating on CSP technology. Crews are shown installing mirrored parabolic troughs at the Solana Generating Station in Arizona. The 280-MW concentrating solar power (CSP) plant is scheduled for completion in 2013. CSP technology uses mirrors to reflect and concentrate sunlight onto receivers that collect the sun's heat. *Courtesy: Dennis Schroeder*



2. Storing solar energy. These tanks at the Solana plant will hold molten salts. Those liquid salt fluids remain very hot for several hours, so the energy stored in them can be recovered to produce steam that can be expanded in the steam turbine on demand to produce electricity later in the day. *Courtesy: Dennis Schroeder*

The dispatchability of CSP with TES can enable higher overall penetration of the grid by solar energy by providing solar-generated electricity during periods of cloudy weather or at night, when PV-generated power is unavailable. Such systems also have the potential to improve grid flexibility, thereby enabling greater penetration of PV energy (and other variable generation sources such as wind) than if PV were deployed without CSP.

Challenges of Solar Deployment at High Penetration

The benefits and challenges of high PV penetration (feeding high percentages of solar generation to the grid) have been described in a number of analyses. At low penetration, PV could displace the highest cost generation sources and may also provide reliable capacity to the system. Figure 3 shows a simulated system dispatch for a single summer day in California with PV penetration levels from 0% to 10% (on an annual basis). This figure is from a previous analysis that used a production cost model simulating the western U.S. This particular scenario illustrates how PV reduces the need for peaking capacity due to its coincidence with demand patterns.

As penetration increases, the value of PV capacity drops. This can be observed in Figure 3, where the peak net load (normal load minus PV) stays the same between the 6% and 10% penetration curves. Beyond this point, PV no longer adds significant amounts of firm capacity to the system.

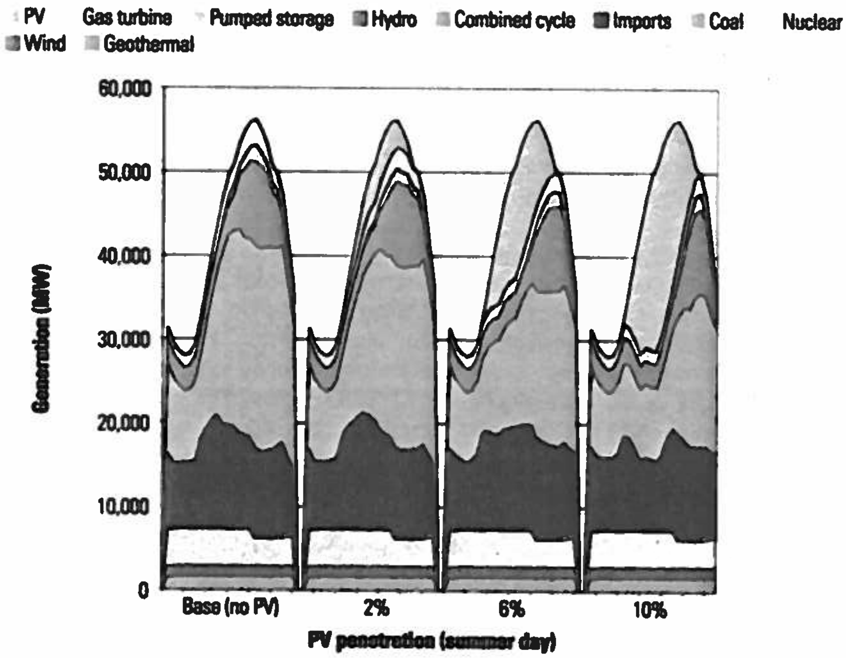
Several additional challenges for the economic deployment of solar PV occur as penetration increases. These are illustrated in Figure 4, which shows the results of the same simulation, except on a spring day. During this day, the lower demand could result in PV displacing lower-cost base-load energy, should CAISO dispatch PV first. At 10% PV penetration in this simulation, PV completely eliminates net imports, and California could export energy to neighboring states, if the cost of the exported power were attractive.

Several factors limit the ability of conventional generators to reduce output to accommodate the variability of renewable generation. One is the rate at which generators can change output, particularly in the evening, when they must increase output rapidly in a high-PV scenario.

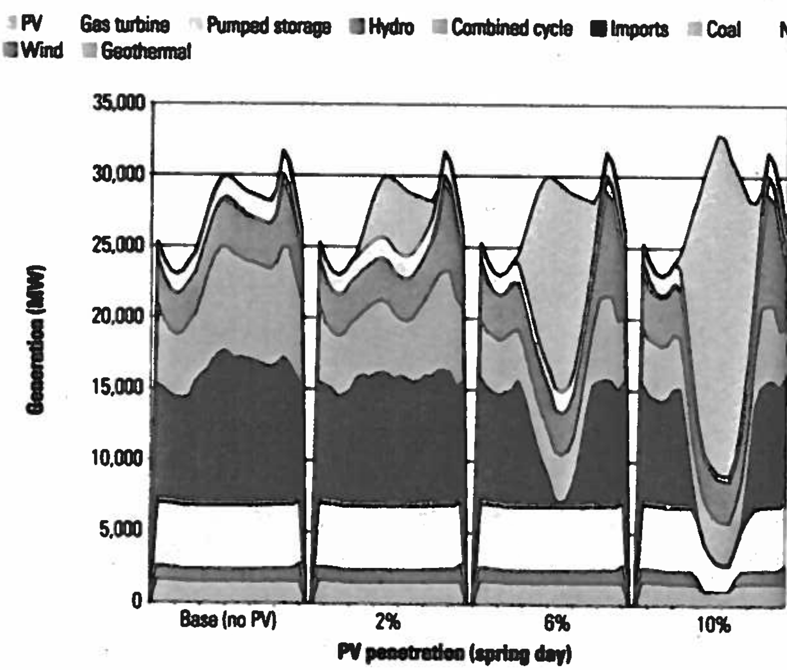
Another limitation is the overall ramp range, or generator turndown ratio. This represents the ability of power plants to reduce output, which is typically limited on large coal and nuclear units. Accommodating all of the solar generation, as shown in Figure 4, requires nuclear generators to vary their output, which is not current practice in the U.S. nuclear industry. Most large thermal power plants cannot be shut down for short periods of time (a few hours or less), although brief shutdowns would be required to accommodate all the energy generated during the period of peak solar output. Additionally, many plant operators have limited experience with cycling large coal plants, and extensive cycling could significantly increase the cost of maintenance. (See "Mitigating the Effects of Flexible Operation on Coal-Fired Plants" and "Make Your Plant Ready for Cycling Operations" in the August 2011 issue of *POWER* or the magazine's archives at www.powermag.com.)

The ability to "de-commit" or shut down power plants may also be limited by the need

3. Syncing up with demand. This chart, showing a simulated dispatch in California for a summer day with PV penetration from 0% to 10%, illustrates how PV has the ability to reduce the need for peaking capacity due to its coincidence with demand patterns. Each set of curves represents a 24-hour day. *Source: National Renewable Energy Laboratory (NREL)*



4. The impact of diminished demand. Simulated dispatch in California for a spring day is shown with PV penetration from 0% to 10%. During this day, the lower demand results in PV displacing lower-cost baseload generation, if PV is dispatched first. *Source: NREL*



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to provide operating reserves from partially loaded power plants. As the amount of PV on the system increases, the need for operating reserves also increases due to the uncertainty of the solar resource, as well as its variability over multiple time scales.

Previous analysis has demonstrated the economic limits of PV penetration due to generator turn-down limits and supply/demand coincidence. Because of these factors, at high penetration of solar energy, increasing amounts of solar generation may need to be curtailed. Generator constraints would likely prevent the use of all PV generation potentially available in Figure 4's 10% scenario. Nuclear plant operators would be unlikely to reduce output for such a short period. Furthermore, PV generation could be offsetting other low- or zero-carbon sources such as wind and geothermal generation.

Although the percentage of solar energy on the U.S. grid is currently far too small to result in significant impacts, the curtailment of wind energy is an increasing concern. Though a majority of wind curtailments in the U.S. are due to transmission limitations, curtailments due to excess generation during times of low net load (as happened last year in the Pacific Northwest with Bonneville Power Administration) are a significant factor that will increase if grid flexibility is not enhanced.

Thermal energy storage provides some potential advantages for bulk energy storage, including round trip efficiency in excess of 95%.

One measure of a flexible grid is the ability of the aggregated set of generators to rapidly change output at a high rate and over a large range. Flexibility depends on many factors, including these:

- *Generator mix.* Hydro and gas-fired generators are generally more flexible than coal or nuclear ones.
- *Grid size.* Larger grids are typically more flexible because they share a larger mix of generators and can share operating reserves and a potentially more spatially diverse set of renewable resources.
- *Use of forecasting in unit commitment.* Accurate forecasting of the wind and solar generation units reduces the need for operating reserves.
- *Market structure.* Some grids allow more rapid exchange of energy and can more efficiently balance supply from variable generators and demand.
- *Other sources of grid flexibility.* Some locations have access to demand response, which can provide an alternative to partially loaded thermal generators for provision of operating reserves. Other locations may have storage assets such as pumped hydro.

Increasing Solar Deployment Using CSP

An alternative to storing solar-generated electricity is storing solar thermal energy via CSP/TES. Because TES can only store energy from thermal generators such as CSP, it cannot be directly compared with other electricity storage options, which can charge from any source. However, TES provides some potential advantages for bulk energy storage, including round trip efficiency in excess of 95%.

As part of our assessment, we used a reduced form dispatch model designed to examine the general relationship between grid flexibility, variable solar and wind generation, and curtailment. We calculated the hourly electrical output of a CSP plant with 8 hours of storage.

5. CSP: the dispatchable renewable energy. Simulated system dispatch is shown from April 7 to 10 with 15% contribution from PV and 10% from dispatchable CSP. This chart illustrates the importance of dispatchability at high solar penetration. The figure shows two CSP profiles. The blue line at the bottom of the chart is the non-dispatched CSP without thermal storage, which aligns well with PV generation. The red line denotes the thermal storage used to shift energy to the end of the day. *Source: NREL*

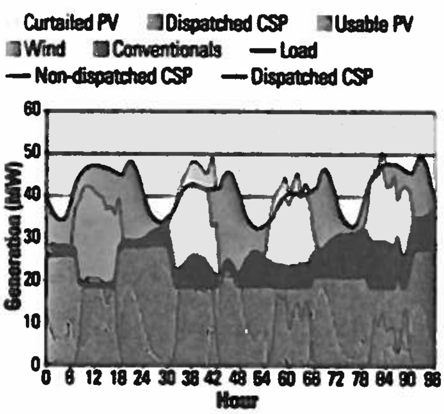


Figure 5 illustrates the importance of dispatchability at high solar penetration over a four-day period. The figure shows two CSP profiles. The "non-dispatched CSP" line (in blue) is the output of CSP alone, without thermal storage; it aligns with PV production when the sun shines, as you would expect. Without storage, the result would be significant CSP curtailment because the sum of CSP and PV generation exceeds the grid energy requirement at that time. The orange line is the actual dispatched CSP but with the effect of TES included, showing its response to the net demand pattern after wind and PV generation are considered. It shows how a large fraction of CSP energy is sent to energy storage to be shifted toward the end of the day, thus allowing the system to absorb more of the PV generation in the middle of the day. In the first day, this ability to shift energy eliminates curtailment of PV generation.

On the other days, the wind and PV resources exceed the "usable" demand for energy in the early part of the day, resulting in curtailed energy even while the CSP plant is storing 100% of thermal energy. However, overall curtailment is greatly reduced.

The addition of CSP/TES can increase the overall penetration of solar by moving energy delivery to the grid from periods of low net demand in the middle of the day to morning or evening.

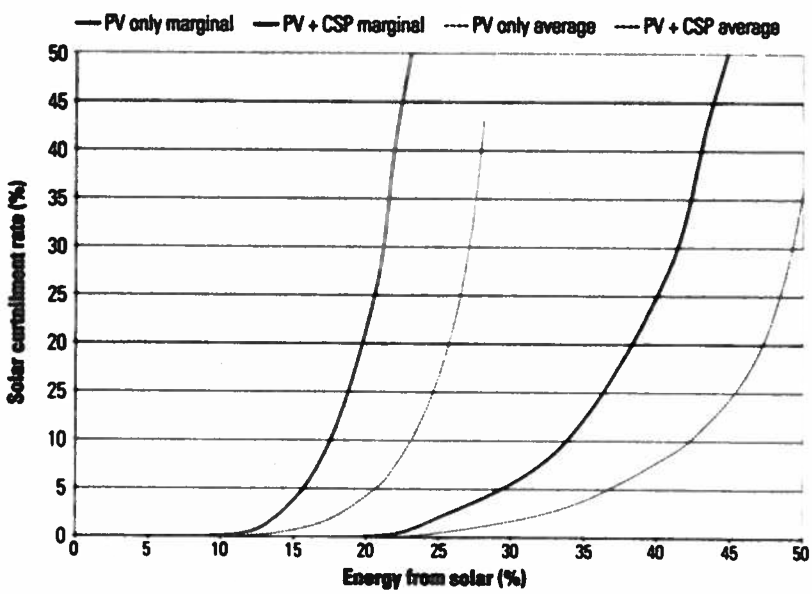
Figure 6 also demonstrates the importance of dispatchability to reduce curtailment and increase the overall penetration of solar via the ability to shift solar energy over time. However, the analysis to this point assumes that CSP and PV are complementary only in their ability to serve different parts of the demand pattern. We have not yet considered the additional benefits of CSP to provide system flexibility by replacing baseload generators and generators online to provide operating reserves.

Adding a highly flexible generator such as CSP/TES can potentially reduce the possible generation constraints on the system. In the near term, this means that fewer conventional generators will be needed to operate at part load during periods of high solar output. In the longer term, the ability of CSP/TES to provide firm system capacity could replace retiring baseload generators.

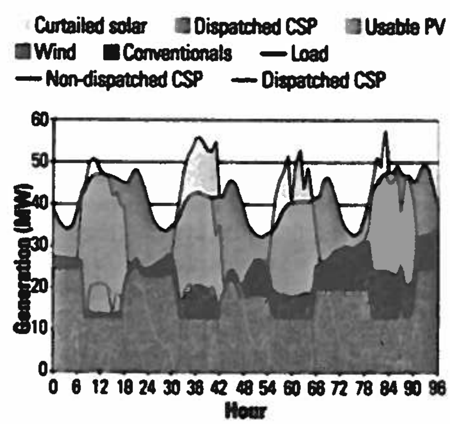
CSP plants with TES add system flexibility because of their fast ramp rate and large operating range relative to large baseload generators. Many CSP plants, both existing and proposed, are essentially small steam (Rankine cycle) plants whose "fuel" is concentrated thermal energy. Few of these plants are deployed, so it is not possible to determine their performance with absolute certainty. However, historical performance of the SEGS VI power plant located in Kramer Junction, Calif., and small gas-fired steam plants provides some indication of CSP flexibility. These plants operate at well over a 50% capacity range with only about a 5% increase in heat rate at 50% load. This provides a strong indication that CSP plants should be able to provide high flexibility.

Implementing a flexible grid, as described above, with solar thermal and PV plants re-

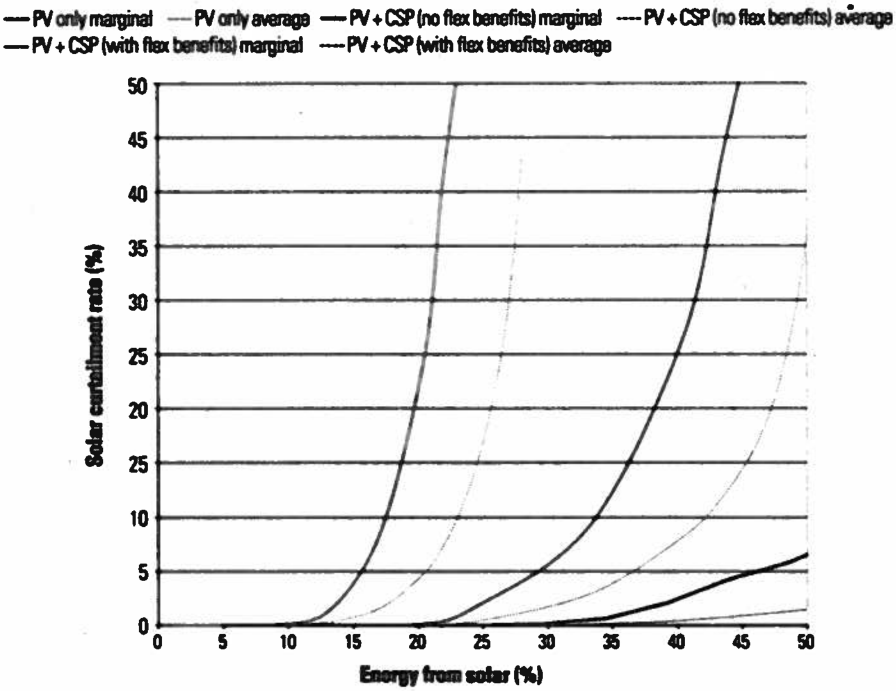
6. Achieving a good balance. This chart depicts the curtailment of solar, assuming an equal mix (on an energy basis) of PV and CSP. This demonstrates how the addition of CSP and TES can increase the overall penetration of solar by moving energy from periods of low net demand in the middle of the day to morning or evening. *Source: NREL*



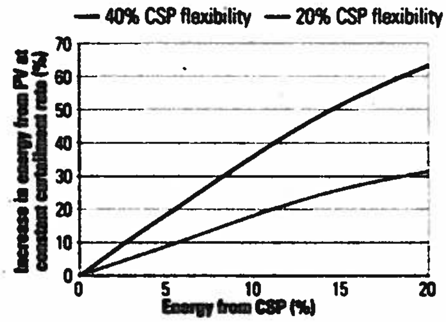
7. CSP boosts PV penetration. Simulated system dispatch from April 10 to 13 is shown with 25% contribution from PV and 10% from dispatchable CSP, where CSP reduces the minimum generation constraint. By shifting energy over time and increasing grid flexibility, CSP enables greater overall solar penetration and, in particular, greater penetration of PV. *Source: NREL*



8. The power of grid flexibility. The curtailment of solar is shown, assuming an equal mix (on an energy basis) of PV and CSP. The chart illustrates the potential overall effect of grid flexibility introduced by CSP and the corresponding opportunities for increased use of PV. *Source: NREL*



9. A dynamic duo. The figure shows the relationship between reducing generation constraints through the addition of CSP/TES and the potential increase in PV penetration. CSP flexibility is defined as the fraction of the CSP rated capacity that is assumed to reduce the system's minimum generation constraint. *Source: NREL*



quires CSP plants that are more flexible in operation than conventional fossil-fueled plants. Because it is not possible to determine the exact mix of generators that would be replaced in high renewables scenarios, we consider a range of possible changes in the minimum generation constraints resulting from CSP deployment.

CSP flexibility is defined as the fraction of the CSP-rated capacity that is assumed to reduce the system's potential generation constraint. For example, deployment of a CSP plant with TES that can operate over 75% of its capacity range could replace a baseload plant that normally operates over 50% of its range. In this scenario, each unit of CSP could reduce the minimum generation constraint by 25% of the plant's capacity.

This very simplistic assumption illustrates how the dispatchability of a CSP plant could allow for a lower minimum generation limit and allow for greater use of wind and PV. As a result, as CSP is added, the grid can actually accommodate more PV than in a system without CSP.

This is illustrated conceptually in Figure 7, which also shows a four-day period. CSP still provides 10% of the system's annual energy, but now we assume that the use of CSP allows for a decreased minimum generation point, and the decrease is equal to 25% of the installed CSP capacity. In this case about 21 GW of CSP reduces the minimum generation point from about 18 GW to 13 GW. This generation "headroom" allows for greater use of PV, and enough PV has been added to meet 25% of demand (up from 15% in Figure 5). As a result, the total solar contribution is now 35% of demand. By shifting energy over time and increasing grid flexibility, CSP/TES enables greater overall solar penetration and greater penetration of PV.

The potential overall impact of the flexibility introduced by CSP/TES and the corresponding opportunities for increased use of PV are shown in Figure 8, which builds on Figure 6 by adding the energy supplied by CSP/TES. The figure assumes that each MW of capacity of CSP energy reduces the minimum generation constraint by 25% of its capacity, and an equal mix of PV and CSP/TES on an energy basis. In this case, the addition of CSP/TES allows PV to provide 25% of the system's energy with very low levels of curtailment.

The relationship between the reduction in minimum generation constraint and potential increase in PV penetration is illustrated in Figure 9, which shows how much more PV could be incorporated at a constant marginal curtailment rate of 20% when CSP is added. In this scenario, the x-axis represents the fraction of annual system energy provided by CSP. Increased penetration of CSP results in a linear decrease in minimum generation constraints. The figure illustrates two CSP flexibility cases. In one scenario, each unit of CSP reduces the minimum generation constraint by 20% of its capacity; in the other, the CSP flexibility is assumed to be 40%. These amounts are not meant to be definitive but represent a possible impact of CSP in reducing minimum generation constraints.

Further Quantifying the Benefits of CSP Deployment

This analysis is a preliminary assessment of the potential benefits of CSP in providing grid flexibility using reduced form simulations with limited geographical scope and many simplifying assumptions. Gaining a more thorough understanding of how CSP can enable greater PV and wind penetration will require detailed production simulations using security-constrained unit commitment and economic dispatch models currently used by utilities and system operators.

Future and ongoing studies at NREL and elsewhere will evaluate the benefits of TES in more detail. To perform these simulations, production cost models will need to include the ability of CSP to optimally dispatch the solar energy resource. These simulations will consider the operation of the entire power plant fleet, including individual generator characteristics and constraints, and the operation of the transmission system. These simulations will provide a better estimate of the benefits of grid flexibility enables by CSP deploying TES. ■

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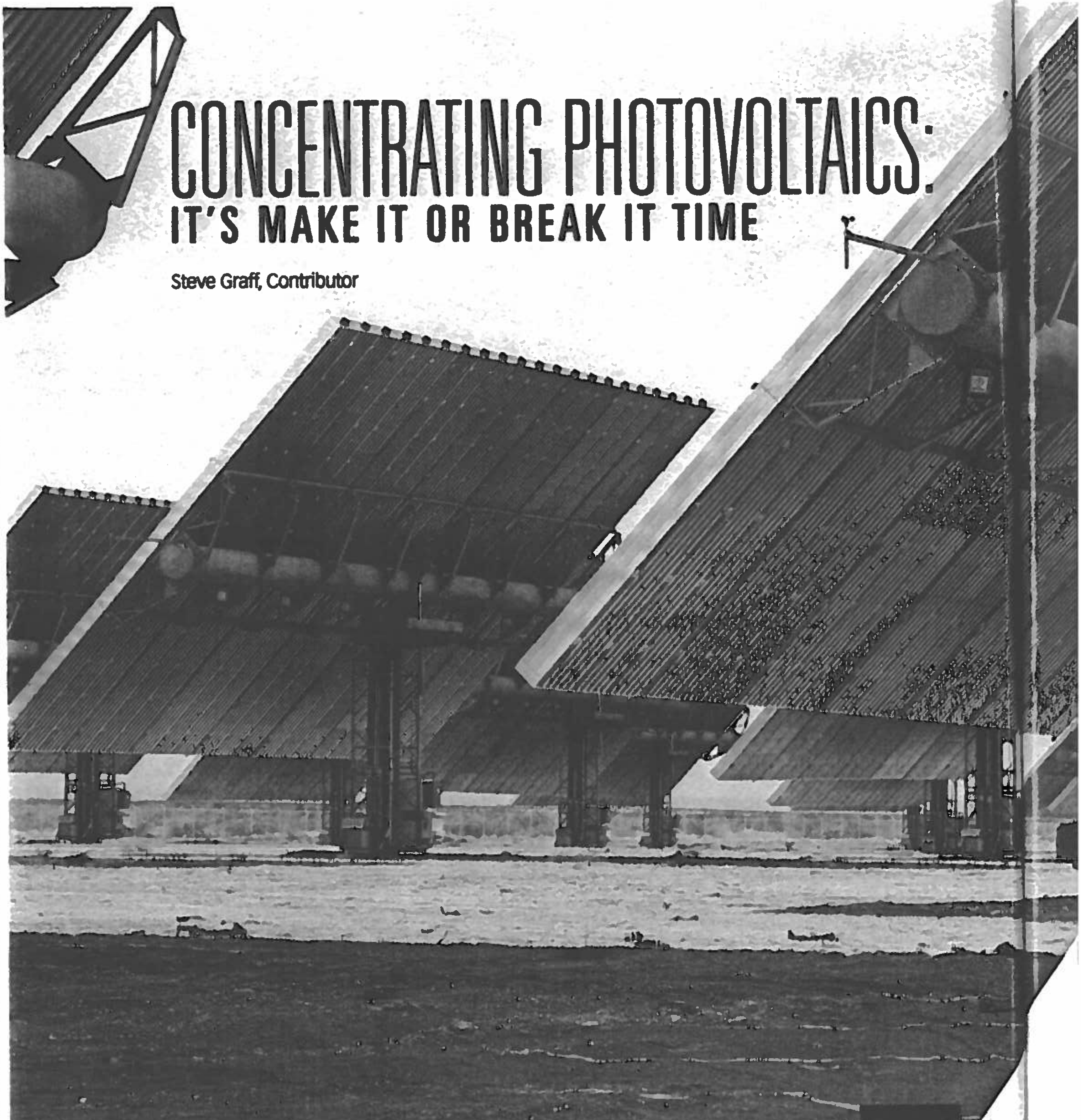
This article is based on an abridged version of the report titled "Enabling Greater Penetration of Solar Power via the Use of CSP with Thermal Energy Storage." The full report (Technical Report NREL/TP-6A20-52978) is available electronically at no cost at www.osti.gov/bridge.

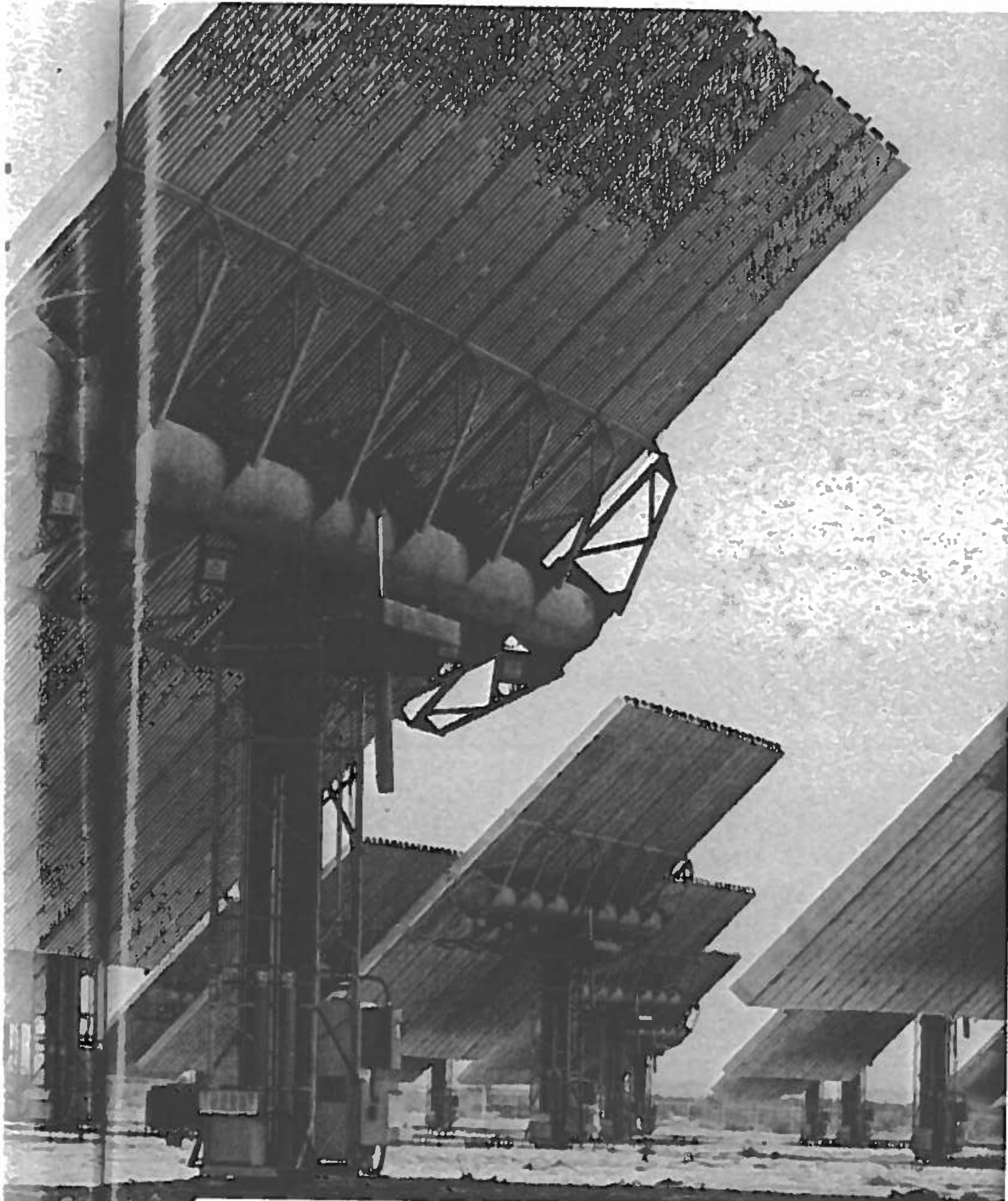
CONCENTRATING PHOTOVOLTAICS:
IT'S MAKE IT OR BREAK IT TIME

Steve Graff, Contributor



Amonix's 5-MW project in Hatch, N.M. Courtesy Amonix.

CPV has talked a good game of potentials in the past few years: potential capacities, potential levelized costs of energy, and potential marketshare. Now, with more than 170 planned projects, many with signed PPAs, the industry needs to prove that it can deliver.



The concentrated photovoltaics (CPV) industry tenaciously pushed through these last four years, and now has 33 megawatts (MW) in the ground, with 60 more expected by mid-year 2012 and about 700 MW more in the pipeline.

Not bad for a relatively new technology, but securing the pipeline and any future projects could make for a tough solar race, as bankability issues loom and cheap PV forces companies to be even more competitive.

"A major challenge for CPV is that their main competitor, traditional PV, has lowered its system price by 30 percent in the last year" said Brett Prior, a senior analyst at GTM Research. "The CPV companies know they need to offer the lowest cost per kilowatt-hour solution or they're not going to win [future] projects."

Starting Up

Early on, because of the price advantages it had over flat-plate or traditional solar PV, CPV found an edge, and a slew of projects happened in climates with high DNI (direct normal irradiance), particularly in the western U.S., Spain, Mexico and Australia. The technology also had efficiency upwards of 40 percent, was faster to install, and didn't need nearly as much water as concentrating solar power (CSP).

The industry went from less than 1 MW in 2009 to 5 MW in 2010. And last year, though far under industry predictions, CPV saw another 500 percent increase. Altogether, there are now 689 MW in the pipeline, according to GTM Research, mostly with projects from today's big industry players, including Soitec Solar, Amonix and SolFocus.

About 289 MW of those pipeline projects are in development with power purchase agreements (PPAs) already in place. Another 207 MW are under development awaiting contracts or Feed-in Tariff confirmation.

Staying Competitive To Move Forward

To keep things in perspective, though, the CPV market still represents a very tiny fraction of the entire solar market, and in fact accounts for less than 0.1 percent of installed solar worldwide. PV still dominates with over 33,000 MW, while CSP represents more than 1,000 MW of installed solar power capacity.

Still, solar analysts predict that 300 MW of CPV will be installed by the end of 2013 and 1 gigawatt will be on the ground by 2015. That's if companies can continue to gain customer confidence and offer better pricing to maintain a lower levelized cost of energy (LCOE).

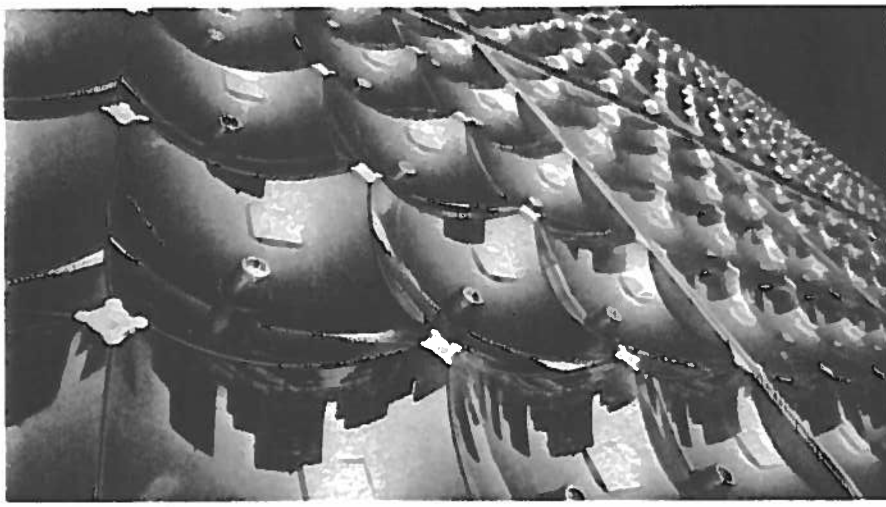
The rapidly falling PV prices have also impacted the CPV industry.

"It has certainly required us to [rethink] our prices," said Nancy Hartsoch, vice president of marketing and business development at SolFocus. "We have to able to price at a much lower dollar-per-watt price than we ever expected a year ago."

However, she points out, CPV is poised to bring down its cost faster than any other solar technologies between now and 2020. According to GTM Research, high-concentrating CPV will have a LCOE of $0.07 kWh by 2020, whereas multicrystalline PV will be about $0.09 kWh.

Carla Pihowich, vice president of marketing and regulatory at Amonix, who said the company has been working with CPV for 16 years and is in its 8th generation of the technology, pointed to that same statistic, but acknowledged today's predicament.

"We are very aware of the rapid decline [of PV prices], and have our finger on the



In 2012, CPV will look to prove its bankability. Courtesy SolFocus.

pulse of where pricing is going," Pihowich said. "But on the positive side, we believe that we are very well-poised going forward; we have a detailed road map to reduce costs — from a design standpoint, from a supply chain standpoint, and from a manufacturing scale standpoint."

There was some pricing hype last year, when four projects in California switched from CSP to PV because it was cheaper. But that isn't necessarily the fate of CPV projects, GTM Research's Prior said. First, overall it was only a small percentage of the MW in the CSP pipeline that switched to PV, and, second, the price difference was more dramatic between CSP and PV, so it just made more sense. "Switching CPV projects isn't as worthwhile in some ways," he said.

Either way, for the CPV industry to take off, companies need to find ways now to get more MW to market to help improve the technology's reliability and bankability. Many may not be making a profit, but at least they are getting the equipment out there, and they are getting to scale.

Creative Energy

There are certainty investors for CPV, but a lot of what's in the ground today and planned for installation in 2012 was funded by independent power producers — who could front the cash. Additionally, the U.S. Department of Energy loan guarantee program helped fund many of the projects.

For now, all eyes are on Amonix's 30-MW Alamosa project, which is under development in Colorado by Cogentrix. It will be the largest CPV project in the world when it is completed sometime in 2012, and one of the first utility-scale CPV projects in the U.S. It managed to secure a $90 million loan guarantee from the DOE, and the first 10 MW should be completed early this year.

Currently the biggest CPV project in the U.S., the 5-MW Amonix project, is now online in Hatch, N.M. with electricity being sold to El Paso Electric under a PPA, which is helping meet the state's Renewable Energy Portfolio Standard. Industrial Revenue Bonds funded that project. (Amonix is responsible for about 19 MW of the total installed capacity today.)

Though it didn't receive a DOE loan guarantee, San Diego's 150 MW Imperial Solar Energy Center West project funded through Tenaska Solar Ventures, which is proposing to use Soitec Solar's technology, is still in development, according to Soitec. That brings Soitec to 305 MW for the area, which includes the 155 MW spread out over five contracts with San Diego Gas & Electric (SDG&E).

With all of these PPAs now approved by the California Public Utilities Commission, Soitec announced in December a $150 million investment into the city by purchasing a manufacturing facility in Rancho Bernardo, Calif. that will support these pipeline projects. It will produce 200 MW of solar modules per year, and is expected to go online late 2012.

SolFocus, which has partnered with Sol Orchard, now has a total of 34 MW in operation or under construction, with projects in Colorado, Arizona, California, Hawaii, Italy, Portugal, Greece, Saudi Arabia, South Africa and Malaysia. Its most recent announcement was a completed 53 kW project in Texas that is owned by El Paso Electric.

According to GTM, CPV solar has 170 projects under development, with most of those in the U.S. "[The industry] finally now has real projects with PPAs," Prior said. "But there's the lynchpin: the hold up is finance."

A big part of the problem is bankability.

Beating Bankability

According to a GTM Research report in 2011, the CPV industry ranks the lowest in bankability, compared with PV and CSP. Older companies with more MW in the ground, like Amonix, may be perceived differently, but overall, the consensus is that bankability is an issue for the industry as a whole.

Now, with so many projects under construction in 2012 and in the pipeline, SolFocus' Hartsoch, who is also a chairperson of the CPV Consortium, said this is the year to show off.

"For a long time, the industry could only talk about what is was going to do, but now it's time to put some meat behind the claims," she said. "I think this industry in the next 12 months has to show its systems and technology are reliable and performing at the level they were predicted to perform."

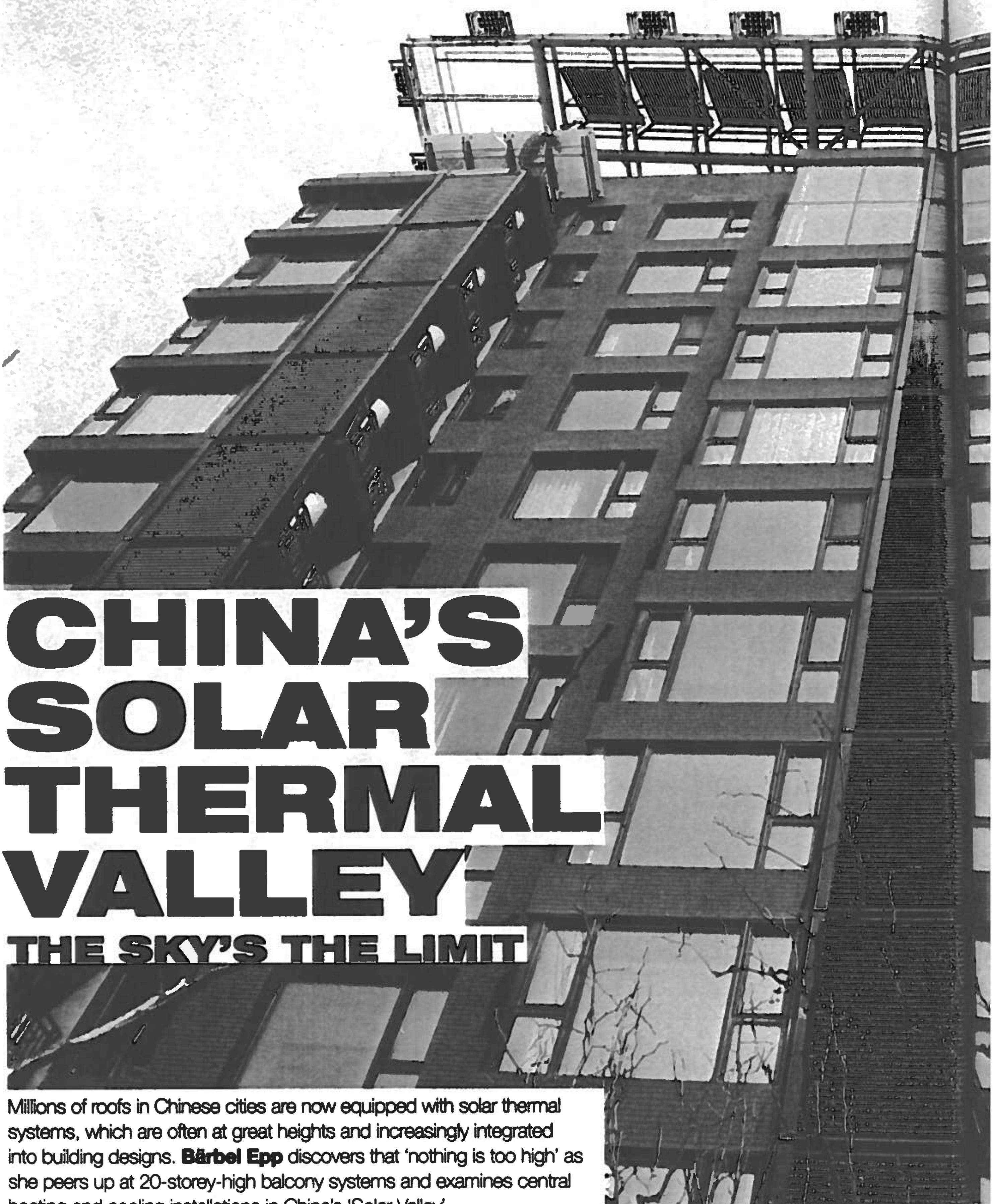
Those two things, she said, will help remove the bankability risk.

Partnerships have also helped. Amonix is working with Boeing. Solfocus obtained technology performance insurance from Munich Re. A first for CPV, the insurance helps SolFocus reduce its technical risk.

The question is whether all the development activity in 2012 will help secure financing for pipeline projects.

"There are a lot solar projects chasing finance. And the finance providers can be picky," Prior said. "It's tough a time to be in the solar market. And it's even tougher to be in the solar market with a newer technology." ■

Steve Graff is a freelance writer who has been featured in the Denver Post and the Journal of the National Cancer Institute. In 2010, he was a principal writer for the U.S. Department of Energy blog "Energy Empowers," where he covered all aspects of the renewable energy and energy efficiency sectors.

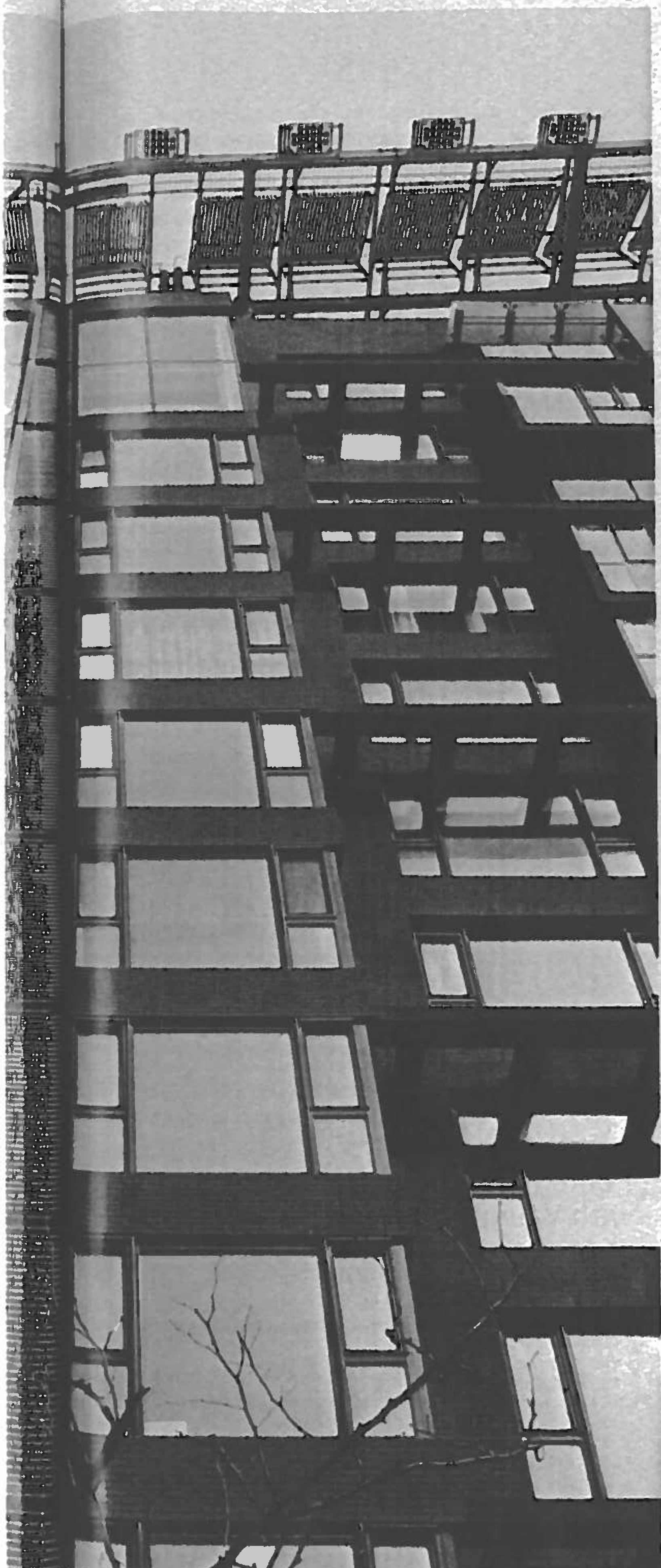


At the Utopia Garden Project, solar domestic hot water tanks rest on balconies behind a facade of horizontal vacuum tubes.
BÄRBEL EPP

CHINA'S SOLAR THERMAL VALLEY

THE SKY'S THE LIMIT

Millions of roofs in Chinese cities are now equipped with solar thermal systems, which are often at great heights and increasingly integrated into building designs. **Bärbel Epp** discovers that 'nothing is too high' as she peers up at 20-storey-high balcony systems and examines central heating and cooling installations in China's 'Solar Valley'.



Ask any six year-old in a Chinese street, 'What's a solar water heater and what's it for?' Without hesitation they will tell you: 'A solar water heater is on the roof of a building to make hot water for the shower'. This story is told by Hongzhi Cheng, vice secretary general of the Beijing-based Chinese Solar Thermal Industry Federation (CSTIF) and head of The Sun's Vision, a company based in the city of Dezhou in Shandong province

Dezhou, one hour by car south of Beijing, has become one of China's solar towns due to the presence of Himin Solar one of the country's largest solar water heater manufacturers. For a German visitor with an interest in solar thermal technology, driving in the city provides an exciting tour past scores of roof and facade installations.

FROM RETROFITS TO CENTRAL SYSTEMS

Dezhou is also a great city to see how the solar thermal industry is developing from retrofitted systems for individual households towards large-scale rooftop solar fields serving entire buildings.

The residential retrofit market, where flat owners install their own solar thermal systems on the roofs of existing buildings, now accounts for some 60% of the market and its share is still edging down says Yunbin Le, deputy general manager at the Sino-German solar water heater manufacturer Linuo Paradigma and its sales director for the Chinese market.

In a simple version of the technology the system owner opens the water tap in the morning and waits until the tank on the roof is full When they come back from work, they can use the heated water until the tank is empty The systems consist of unpressurised water-filled vacuum tubes and the shower water flows directly through the tube and the tanks

Next generation of solar water heaters are found on large apartment buildings, which represent a rapidly growing market segment The new clients are housing companies that design roofs to host enough thermosiphon systems for each flat to be sold with solar hot water These housing companies must meet solar obligations imposed by several cities and municipalities since the Renewable Energy Law of 2006 Most local governments now require solar water heaters to be installed in new civil buildings of up to 12 storeys

'As a builder you do not receive building permission from the municipality unless you have demonstrated the plan for integrating solar hot water into the building says says Fude Li, a project engineer for Linuo Paradigma.

In a new apartment building with Linuo Paradigma solar water heaters in Jinan in Shandong province (see overleaf), the solar systems are attached to cement blocks that are integrated into the roof during construction They are also equipped with temperature and water level sensors so they can fill up automatically

BUILDING-INTEGRATED SYSTEMS TAKE OFF

The third generation of solar thermal technology in China consists of building-integrated systems. Himin Solar is blazing a trail with several demonstration projects in Dezhou's 'Solar Valley'.

Utopia Garden Project is one of the Solar Valley's most recent multi-family buildings, where flats of 300–600 m^2 nestle amid verdant gardens and combine energy-efficiency standards with renewable energy supplies. Marketing the flats, along with the construction and design of their ecological housing technology is in the hands of Himin Solar Energy Real Estate a subsidiary of Himin Solar Group

The 'demonstration of future modern living' is what makes people buy the flats, says Chen Ping of Himin Solar's brand management


In a new apartment building solar systems are attached to cement blocks integrated into the roof during construction.

department. 'The price of the flats is around RMB12,000 (US$1900) per square metre, around 50% higher than comparable apartments because of the advanced renewable energy technology and the intelligent home technologies,' she says. But she claims their owners will pay as little as a quarter of normal energy costs.

Four blocks with a total of 298 flats have already been sold and occupied. Two more blocks are under construction. These buildings' rooftop solar installations are visible from some distance, with 504 vacuum tube collectors arranged horizontally in massive wave-shaped metal stands extending for several metres above the buildings. With a gross collector area of about 756 m^2, the pressurised heat-pipe vacuum tubes supply central heating and cooling systems for entire building complexes. Surplus heat is stored underground in seasonal borehole storage.

Yet central solar heating and cooling systems still provide only a minor share of the solar thermal market. 'Larger installations provided up to 15% of the total market volume in 2011, whereas 85% is still residential,' says Jiuwei Wang, Himin's deputy general manager and chief marketing director.

PRESSURISED BALCONY SYSTEMS

Each flat at these new developments also includes a vacuum tube collector installed in the facade and a 300-litre tank on the balcony to supply hot water. These solar systems represent a totally new generation of residential solar water usage in China. They are pressurised, indirect systems with u-pipe collectors, and a closed-loop solar circuit filled with glycol. If the facade collector fails to reach 60°C, the electric element in the tank does the rest. Solar domestic hot water is therefore separate from the buildings' central heating and cooling system.

Despite being far more expensive than retrofitted, open-loop solar water heaters, these balcony systems still enjoy high demand, says Yunbin Le from Linuo. 'Today 180-litre systems are more common than 100-litre systems.'

In Linuo Paradigma's solar shop in Jinan a 100-litre balcony system with 13 tubes is sold, including installation, at RMB6880 – almost twice as much as a pressureless system with 18 tubes.

Shop prices for systems from Sangle Solar Energy, another of China's five biggest solar water heater manufacturers, are generally 10%–15% lower than for Linuo Paradigma, yet display a similarly large gap between the two technologies. Customers pay RMB5860 for a closed-loop balcony system with a flat plate collector and a double wall tank, or no more than RMB2690 for a pressureless solar water heater with 20 water filled tubes and a 180-litre tank.

Aesthetic tastes seem to decide whether companies pick vacuum tubes or flat-plate collectors, says Chen Liang, marketing planner for international business development at Sunrain Group, China's largest manufacturer of solar water heaters in 2011. 'Flat-plate collectors in the facade are more beautiful than vacuum tubes, according to building designers,' he says.

SALES DOUBLE FOR BALCONY SYSTEMS

Balcony systems are popular for multi-family buildings that lack roof space for a solar unit for each apartment. 'We produced 60,000 tanks for balcony systems last year and we expect a doubling this year,' says Jie Xu, Linuo Paradigma's production manager.

Linuo Paradigma's solar tank manufacturing and system assembling factory in Jinan produced one million sets in 2011. Its 300 full-time workers produce 784 different tank models, sold both as OEM units and under the Linuo Paradigma brand.

The company also recently opened an automated 'tank-in-tank' production line for balcony systems. Pressurised enameled cylinders for domestic hot water are purchased externally. All manufacturing steps are performed in a single, highly automated U-shaped line: screen printing, punching and bending of the tank jacket, inner tank pressure testing, preassembling, foaming with polyurethane insulation as well as packaging. 'We can run the whole line with a maximum capacity of 500 tanks a day with around 30 workers,' says Jie Xu.

Linuo Paradigma's balcony systems all feature vacuum tube collectors. To improve the thermosiphon flow in the solar circuit of balcony systems, the company has developed a special type of u-pipe vacuum tube. The copper piping in the horizontal tubes has more the form of a V than a U. Continuously rising pipe supports the natural flow of the hot water to the tank above the collector. 'We do not see technical problems with vacuum tubes in the facade up to 36 floors,' says Yunbin Le.

China's tall buildings seem to have no upper limit for solar thermal installations. The industry aims high and still has huge growth potential, says Hongzhi Cheng. 'Only 30% of the market demand is fulfilled yet in the rural area. We expect the rural segment to grow [from around RMB100 billion ($15 billion) today] to RMB600 million.' But he predicts even stronger growth of thousands of billions of renminbi for the large-scale solar thermal sector. European visitors will then be astonished by even more solar thermal installations on Chinese skylines.

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